Cooperative Mobile Sensing Networks

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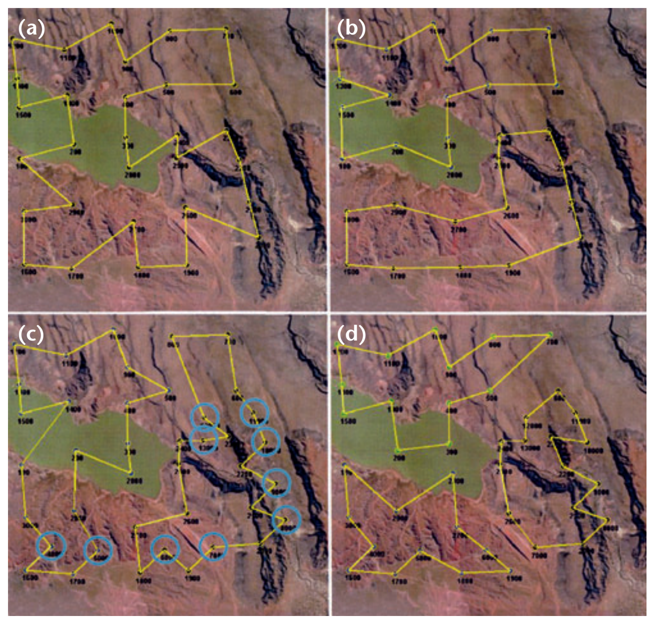
Low-cost, high-endurance unmanned air vehicles (UAVs) are now practicable for autonomous sensing and data collection over wide areas. UAVs can collect data either with onboard sensors or by receiving and relaying data from ground-based sensors. Using a network of UAVs to collect sensor data would provide advantages such as quicker data collection and the ability to adapt to the loss of an individual UAV. Applications of UAV networks include providing communication services to isolated ground sensors, aerial monitoring of national borders and seaways for homeland security, and air sampling for atmospheric modeling.

Our project investigated two fundamental requirements for using UAV networks to autonomously collect sensor data: 1) route optimization—constructing efficient routes that allow the UAVs to collect data without duplicating effort or interfering with one another; and 2) control architectures for network adaptation—allowing a network of UAVs to optimally adapt to exceptional events, such as the loss or addition of UAVs to the network or changes in the priorities of subregions in the area covered. By potentially enabling data collection by UAV, this project supports LLNL's missions in national security and environmental management.

In FY02, we completed our investigation into UAV control architectures and network adaptation schemes, including improving our route-optimization algorithm to better process information about sensing cost—the effort required for a UAV to complete a data-collection route. Cost information is regularly estimated by each UAV and shared throughout the network. This work resulted in control architectures based on hierarchical or distributed control. In the hierarchical architectures, network adaptation is initiated by one lead UAV, which can be replaced by any other UAV should it be disabled. This type of architecture is useful in small networks requiring quick adaptation. In the distributed architectures, UAVs cooperatively perform network adaptation by individually optimizing sensing costs for their subregions. These architectures are useful in large networks in which subregion sensing costs can change abruptly—for instance, if a UAV had to remain over a specific location to video a convoy of vehicles.

In collaboration with the University of California, Davis, we continued developing a software tool called STOMP, which stands for simulation, tactical operations, and mission planning. STOMP implements the control architectures described above to simulate, control, and communicate with UAVs used in sensing applications. The figure gives an example of network adaptability when increasing the number of UAVs and sensing points in a network. The capabilities of STOMP include simulations in which real UAVs and sensors interact with the virtual UAVs and sensors. This capability enables experiments to determine whether a sensing task requires more sensors and UAVs than are on hand.

Finally, we conducted several experiments in which an airborne UAV collected imagery from unattended ground sensors and transmitted the data to a ground station. These experiments allowed us to test the communications modules developed during FY00 and refine the data-transfer techniques developed during FY01. The results of these experiments were applied to the design of the STOMP communications objects. In summary, we developed a data-collection architecture in which UAVs collect data adaptively and cooperatively.



An example of adaptability in a network of unmanned air vehicles (UAVs) controlled with the simulation, tactical operations, and mission planning (STOMP) tool. (a) First, an area is covered by one UAV collecting data at sensing points along a route. (b) A second UAV is added, and the area is divided into two routes for faster data collection. (c) Surveillance resolution is increased by adding sensing points. (d) A third UAV is added.